Nonlinear Time-Dependent Currents in the Surf Zone

Donald N. Slinn
Department of Civil and Coastal Engineering
University of Florida
Gainesville, FL 32611-6590
Phone: (352) 392-1436 x 1431 Fax: (352) 392-3466 E-mail: slinn@coastal.ufl.edu

Award #: N00014-99-1-0489 and N00014-02-1-0148
http://www.ce.ufl.edu/people/faculty/alpha/slinn.htm

LONG-TERM GOALS

The goals of this work are to develop better understanding and predictive capability for nearshore currents forced by breaking waves in the surf zone.

OBJECTIVES

The major tasks have been to:

(1) Couple the wave field to the evolving currents in physical-mathematical models for situations that produce alongshore and rip currents. As currents evolve, the distribution of surface wave breaking adjusts because of the wave refraction caused by the currents. Subsequently, the momentum input to the currents is altered. We have examined the influence of feedback from the currents on the wave radiation stress gradients that parameterize momentum forcing from wave breaking.

(2) Examine rip current dynamics for different parameter ranges of wave height, incident wave angle, bottom friction, and beach bathymetry.

(3) Investigate the influence of roller models, non-linear bottom friction, and data assimilation on model predictions.

(4) Simulate field conditions at Duck, N.C. using measured beach bathymetry and wave field conditions from the Delilah and Sandy Duck experiments. This "best effort" model includes, non-linear bottom friction, different wave-breaking models, and coupled wave-current interactions.

(5) Utilize the model in a forecast mode in collaboration with field experiments led by R.T. Guza on Scripps beach.

APPROACH

The work involves theoretical development, numerical computations, and comparison with field and laboratory results. The primary experimental tools are the depth-integrated and time-averaged (with respect to the wave period) shallow water equation models including parameterization for the wave forcing effect, horizontal diffusion, and bottom friction (Slinn *et al*., 1998, 2000). Process studies are conducted for different key nearshore parameters (incident wave angle, wave height, bottom friction parameterization, beach bathymetry, *etc*.) to determine the effects on the flow response.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2002		**00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE
Nonlinear Time-Dependent Currents in the Surf Zone

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Department of Civil and Coastal Engineering,,University of Florida,,Gainesville,,FL, 32611

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The goals of this work are to develop better understanding and predictive capability for nearshore currents forced by breaking waves in the surf zone.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

The numerical model has been modified to couple the wave refraction with the evolution of currents. The effects of wave-current interaction have been tested on rip currents (Yu and Slinn, 2002, in press) and alongshore currents (McIlwain and Slinn, 2002). A new non-linear bottom friction sub-model has been developed, based on an integration of the flow velocity over a wave period. This model was compared to the Wright and Thompson 1983 (WT) bottom friction correlation. The non-linear Manning-Strickler equation was used to give a non-linear drag coefficient for some simulations. Existing wave-breaking models have been modified with a new two-dimensional time-dependent roller model for obliquely incident waves, similar to the Reniers *et al*. (1997) formulation. The modeled wave heights and mean alongshore currents for alongshore uniform barred beaches obtained using non-linear bottom friction and the new roller model have been compared to averaged Delilah field data. Effects of different parameterizations for horizontal diffusion have been examined and shown to be less significant than adjustments to the wave breaking parameterization.

RESULTS

The numerical results consistently show that the offshore extent of rip currents is significantly reduced when wave-current interaction is included (Yu and Slinn, 2002). The effects of wave-current interaction are less significant on the mean flows for alongshore-uniform beach simulations.

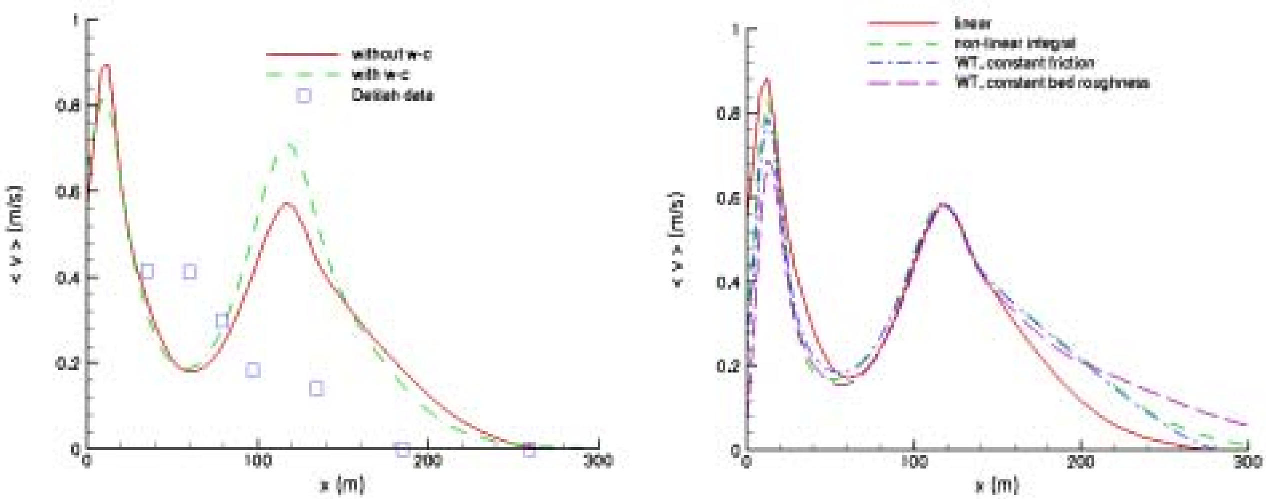

Figure 1: Effects of including wave-current interaction and different bottom friction models on the alongshore averaged alongshore current.

A plot of the predicted alongshore-averaged alongshore current on a uniform barred beach with and without wave-current interaction, and with four different bottom friction models is shown in Figure 1. The x coordinate gives the distance from shore. The friction coefficients used in each model are adjusted to provide similar magnitudes of the alongshore current at $x = 100$ m. The plot indicates that the new non-linear bottom friction model and the two simulations that use the WT correlation predict similar alongshore currents. The non-linear sub-model, however, requires twice the computational

time as the WT correlations. The curve for the linear bottom friction model is larger than the other three curves when $x < 60$ m. The vorticity field ζ predicted with and without wave-current interaction and the effects of enhanced horizontal diffusivity with a constant drag coefficient are shown in Figure 2. Vortex structures form seaward of the sand bar (located at $x = 60$ m) and are periodically shed outwards from the alongshore current (for example, see $x = 300$ m, $y = 600$ m; panel A).

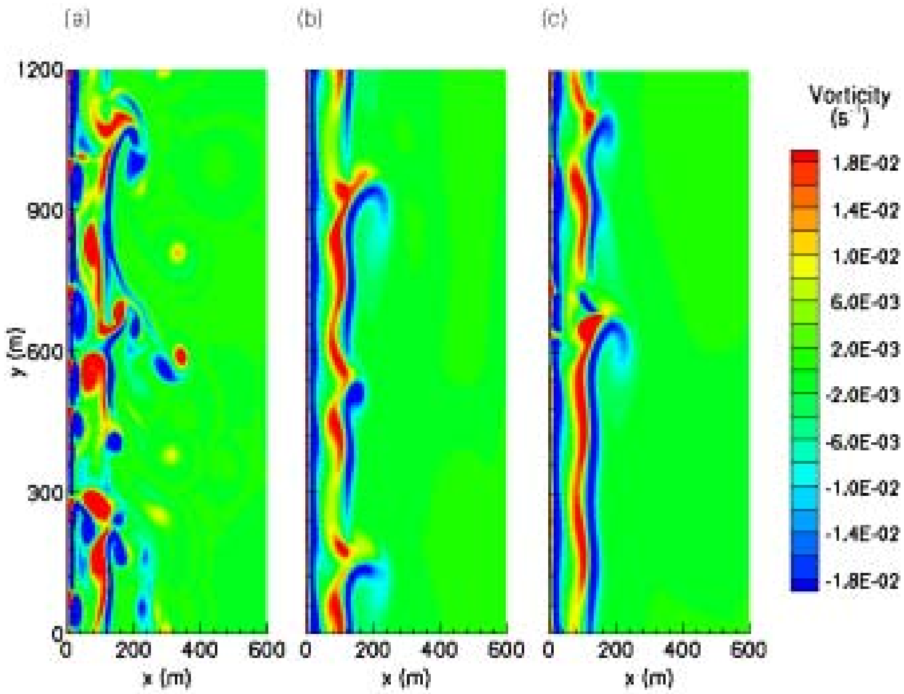

Figure 2: Instantaneous vorticity fields predicted (a) without wave-current interaction or parameterized horizontal mixing, (b) without wave-current interaction, but including parameterized horizontal diffusivity, and (c) with wave-current interaction and horizontal mixing.

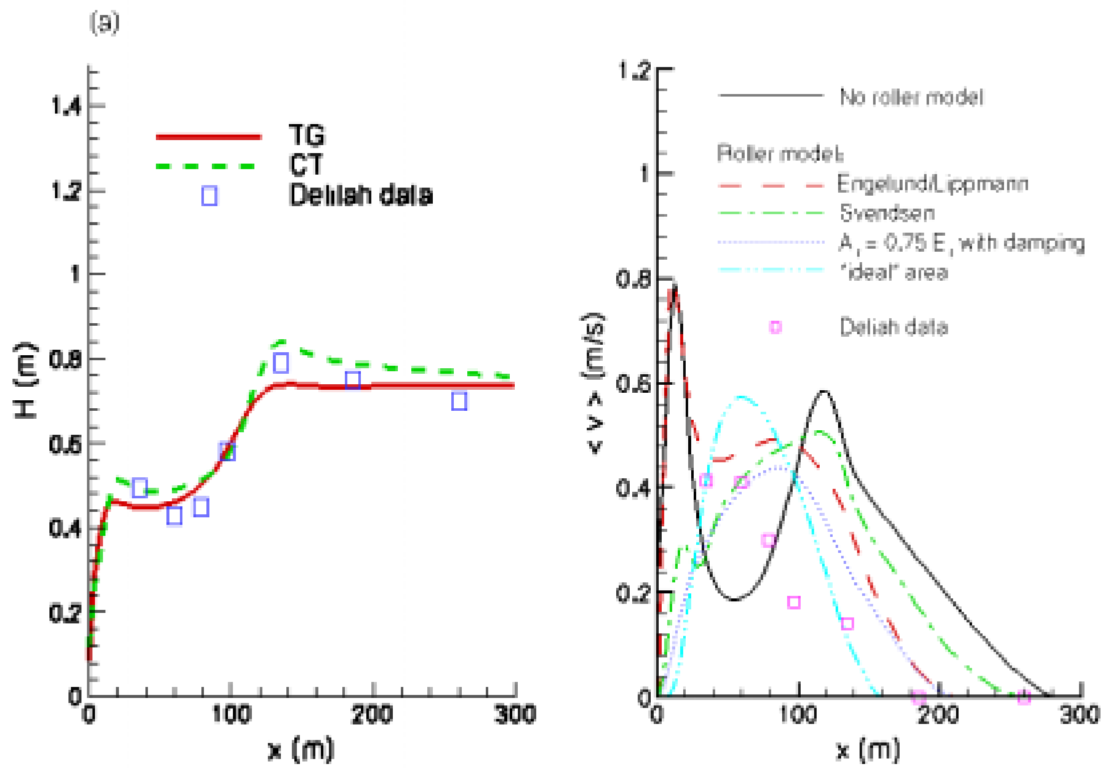

Figure 3: Wave height predictions using the Thornton-Guza and Church and Thornton models compared to the Delilah field data and effect of the roller model on the average alongshore current.

The predicted alongshore currents obtained using different roller sub-models in the wave-breaking model are compared to field data in Figure 3. The same formulation is used for all roller models; only the roller area (A) is varied as indicated in the legend. Roller models 1 and 2 use roller areas that appear in the literature; roller model 3 uses a newly developed roller area. H is the height of the waves as a function of x, H_b is the height of the waves when they break, h is the water depth, σ is the angle of the wave/roller interface, and E_r is the energy of the roller. The roller area was damped to zero when $x < 20$ m in roller model 3. All simulations use the WT bottom friction correlation with a constant drag coefficient. The simulation without a roller model predicts two peak alongshore current velocities at $x = 20$ and 130 m. Neither of these peaks coincides with the maximum current velocity indicated by the field data. The nearshore peak appears because the model forces the wave energy to zero at the shore, and a current is created as the energy is dissipated. The second peak is located seaward of the sandbar, whereas the field data indicate that the maximum current is located in the trough, shoreward of the sandbar. A roller model stores a portion of the wave energy that is released as the wave breaks, and releases that energy closer to the shore, thereby shifting the second peak shoreward. This occurs when roller models 1 and 3 are used. The roller model can also reduce or eliminate the first peak because the energy of the roller is not forced to zero at the shore, such as the case with roller model 3. An ideal roller area can be derived from the model equations (roller model 4), but this area has very little physical meaning. The best physical roller model is based on the energy of the roller field (model 3). Figure 4 shows results from a simulation over complex bathymetry, as measured at Scripps beach during a drifter release experiment.

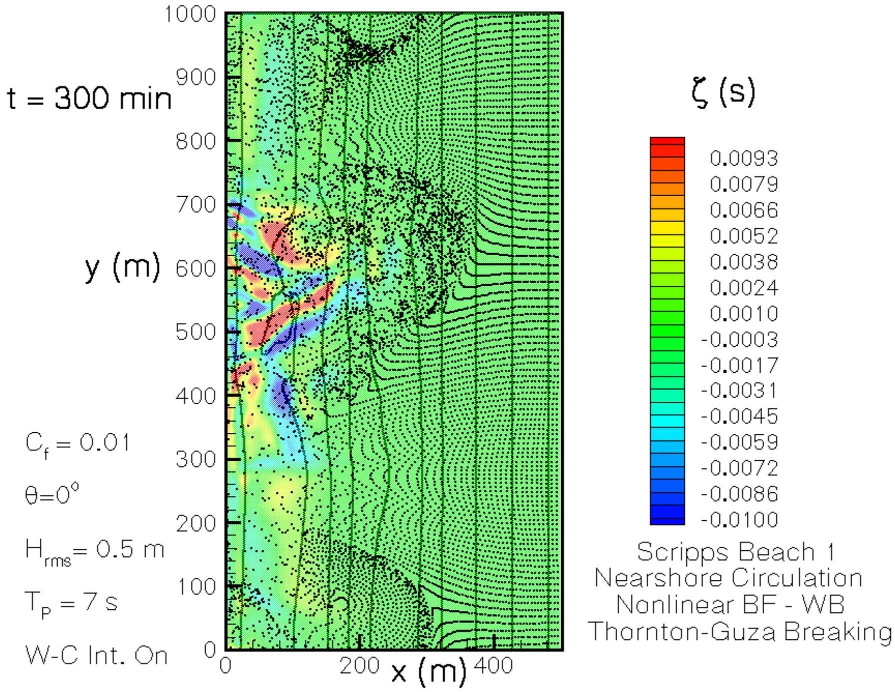

Figure 4. Vorticity fields, depth contours, and Lagrangian "particle" locations from a simulation using topographic and wave field conditions measured at Scripps Beach during a drifter experiment.

IMPACT/APPLICATIONS

Improved understanding of the near shore environment has potential benefits for society in several areas. These include shore protection against beach erosion, understanding the behavior of shoaling waves, keeping waterways open for shipping in harbors, ports and inlets, safety for recreational beach users (e.g., from dangerous rip currents) and in defense of the nation when activities encompass littoral regions. We will have a strong indication that we understand and can quantify important nearshore processes when predictive models can match field observations. For the scientific community, this is still a work in progress.

TRANSITIONS

Our major transition has been to begin real-time forecasts of nearshore circulation and simulated Lagrangian drifters for Scripps Beach in collaboration with R.T. Guza and W. Schmidt of S.I.O.

RELATED PROJECTS

1. R.T. Guza at Scripps Institution of Oceanography has collected valuable field data using drifters and in-situ instrumentation for calibration and testing of our model skill.

2. A group of near shore researchers, led by Jim Kirby at the University of Delaware, are developing near shore community models. We expect to benefit from and contribute our ideas to their modeling studies.

REFERENCES

Reniers, A.J.H.M. and J.A. Battjes 1997: A laboratory study of longshore currents over barred and non-barred beaches, Coastal Eng., 30, 1-22.

Slinn, D. N., J. S. Allen, P. A. Newberger, and R. A. Holman 1998: Nonlinear shear instabilities of alongshore currents over barred beaches, J. Geophysical Res., 103, 18357-18379.

Slinn, D. N., J. S. Allen, and R. A. Holman 2000: Alongshore currents over variable beach topography, J. Geophysical Res., 105, 16971-16998.

Wright, D.G. and K.R. Thompson 1983: Time-averaged forms of the nonlinear stress law, J. Phys. Oceanography, 13, 341-346.

PUBLICATIONS

Slinn, D. N., J. S. Allen and R. A. Holman 2000: Alongshore currents over variable beach topography, J. Geophysical Res., 105, 16,971-16,998.

Yu, J. and D. N. Slinn, 2002: Effects of wave-current interaction on rip currents, in press, Journal of Geophysical Research – Oceans.

McIlwain, S. and D. N. Slinn, 2002, Modeling alongshore currents over barred beaches, submitted to the Journal of Geophysical Research – Oceans.